161-kV OPTION E EVALUATION

Columbia Water & Light

Option E Evaluation
BMcD Project No. 104146

Revision 1
7/6/2018

161-kV OPTION E EVALUATION

prepared for

Columbia Water & Light
Option E Evaluation
Columbia, MO

Project No. 104146

Revision 1
7/6/2018

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, MO

INDEX AND CERTIFICATION

Columbia Water & Light
161-kV OPTION E EVALUATION
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Report Index

Chapter Number	Chapter Title	Number of Pages
1.0	PURPOSE	1
2.0	ROUTE OVERVIEW	1
3.0	PROJECT ASSUMPTIONS	1
4.0	STRUCTURES	8
5.0	PROPOSED CORRIDOR	3
6.0	STRUCTURE SPOTTING	1
7.0	CORRIDOR CONSTRAINTS	4
8.0	ACREAGE IMPACT	2
9.0	SUMMARY	1
Appendix A	Appendix Name	4

Certification

I hereby certify, as a Professional Engineer in the state of Missouri, that the information in this document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the Columbia Water & Light or others without specific verification or adaptation by the Engineer. Furthermore, no part of this report is intended to be understood as final design or for construction. The two cost opinions included in this submittal as well as any land cost values that may be added by Columbia Water & Light are explicitly excluded from this seal.

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TABLE OF CONTENTS

Page No.

1.0 PURPOSE 1-1

2.0 ROUTE OVERVIEW 2-1
2.1 McCredie-Overton 2-1

3.0 PROJECT ASSUMPTIONS 3-1

4.0 STRUCTURES 4-1
4.1 Structure Configurations 4-1
4.1.1 H-Frame with I-String 4-1
4.1.2 Monopole with I-String 4-2
4.1.3 Monopole with Braced Posts 4-3
4.2 Structure Material Selection 4-5
4.2.1 Wood 4-5
4.2.2 Steel 4-6
4.3 Existing 345-kV Structure Re-use 4-7
4.3.1 Existing Structure Strength 4-7
4.3.2 Electrical Clearances 4-7
4.3.3 System Planning 4-8

5.0 PROPOSED CORRIDOR 5-1
5.1 345-kV to 161-kV Spacing 5-1
5.2 161-kV to Edge of ROW 5-1

6.0 STRUCTURE SPOTTING 6-1

7.0 CORRIDOR CONSTRAINTS 7-1
7.1 Bolstad Substation Area (Region 1) 7-1
7.2 Brown Station Road to Highway 63 (Region 2) 7-1
7.2.1 Combined 345/161-kV Structure 7-2
7.3 North Creasy Springs to North O Neal Road (Region 3) 7-2
7.3.1 Double Circuit 345/161-kV 7-2
7.3.2 Property Acquisition 7-3
7.4 Ameren Structure 679 (Region 4) 7-3
7.5 Perche Creek Crossing Area (Region 5) 7-3
7.6 Perche Creek Substation Area (Region 6) 7-4

8.0 ACREAGE IMPACT 8-1

9.0 SUMMARY 9-1

APPENDIX A - OPTION E MAP

LIST OF TABLES

Page No.

Table 3-1: Project Design Assumptions 3-1
Table 4-1: Tangent Structure Configuration Comparison 4-4
Table 4-2: Structure Material Comparison 4-6
Table 5-1: Minimum Additional ROW Width Required... 5-2
Table 8-1: Acreage Impact of Additional ROW required 8-1
Table 8-2: Acreage Impact by Zone 8-2

LIST OF FIGURES

Page No.

Figure 4-1: Conceptual I-string H-Frame Configuration 4-2
Figure 4-2: Conceptual I-String Monopole Configuration 4-3
Figure 4-3: Conceptual Braced Post Monopole Configuration 4-4
Figure 5-1: Minimum Additional ROW Width Required 5-3

1.0 PURPOSE

Columbia Water & Light (CWL) has requested Burns & McDonnell to provide a high-level analysis and evaluation of a proposed 161-kV transmission line route. The proposed route, herein referred to as Option E, was selected by CWL in an effort to leverage the existing Right-of-Way (ROW) of the existing Ameren-owned McCredie-Overton 345-kV transmission line. The purpose of the evaluation is to study the feasibility of the route, determine potential impacts to the existing parallel 345-kV circuit, and to develop cost and acreage impacts of the new route.

2.0 ROUTE OVERVIEW

Option E begins at the CWL-owned Bolstad Substation in northeast Columbia, approximately one-half mile east of the intersection of Brown Station Road and Peabody Road. Near the intersection of Brown Station Road and Peabody Road, the proposed Option E begins to parallel Ameren Services Company's (Ameren) existing McCredie-Overton 345-kV transmission line for approximately 10 miles. Option E then diverges from the McCredie-Overton line south of Interstate 70 near the Midway Golf Complex. Option E then continues south approximately two miles and turns east approximately one mile to its termination at the CWL-owned Perche Creek Substation. The total distance of Option E is approximately 13.4 miles.

2.1 McCredie-Overton

McCredie-Overton is an existing 345-kV transmission line owned by Ameren. Based on publicly available data, the line is predominately supported by wood h-frame structures (two vertical wood poles with a horizontal cross arm supporting the three phases). Each phase has two separate conductors per bundle. Each pole has a shield wire near the top for a total of two per structure. Depending on the height of the structure, the h-frames utilize one or more cross braces between the vertical poles.

In May 2017, at the request of CWL, Ameren completed a report titled "*Study Report: McCredie-Overton Transmission Line Right-of-Way Analysis*" (Ameren Report). The purpose of the initial Ameren Report was to review the existing line to determine the offset required between the CWL proposed 161-kV line and their existing 345-kV line, review the existing 345-kV corridor for buildings, residences, and other obstructions that could impact a new 161-kV line, and to review the existing 345-kV easement language to determine if a new 161-kV line within the existing 345-kV ROW is suitable from a legal perspective.

The Ameren Report noted that there are no known legal restrictions to co-locating a 161-kV transmission line within the existing 345-kV ROW. Based on the report, the existing McCredie-Overton 345-kV line utilizes a 150-foot wide ROW, which Burns & McDonnell has assumed the existing line is centered within this ROW. In addition, the report includes minimum offset distances from the existing 345-kV line to any future 161-kV line. This value was used as a starting point for the proposed Option E centerline and discussed in Section 5.0.

3.0 PROJECT ASSUMPTIONS

The feasibility of the route, conceptual structure layouts, and resulting project recommendations are based on a number of design assumptions. The design assumptions for this evaluation are based on industry codes and standards, common industry practice, engineering experience, and discussions with CWL staff. Table 3-1 below summarizes the assumptions used for the Option E evaluation.

Table 3-1: Project Design Assumptions

CATEGORY	VALUE	REFERENCE
Existing 345-kV ROW Width	150 feet	Ameren Report
Proposed span length	800 feet	Approximate average span length of McCredie-Overton line based on CWL provided data
Proposed phase wire type	795 kcmil ASCR "Drake"	CWL direction
Proposed shield wire	½" EHS steel	CWL direction
Wire tension limits	Varies	National Electric Safety Code (NESC) C2-2017 Section 261
Maximum operating temperature	212 Deg F	Common Industry practice
Electrical clearance to ground	25 feet	NESC C2-2017 Section 23 and Rural Utility Service (RUS) Bulletin 1724E-200
Proposed offset to McCredie-Overton line	71 feet (CL of 345kV to wire attachment of 161kV)	Ameren Report
Proposed structure geometry	Varies	RUS Bulletin 1728F-811
Approximate insulator length	6 feet	RUS Bulletin 1724E-200

4.0 STRUCTURES

Based on industry experience, proposed structure types were evaluated for both configuration and material. Burns & McDonnell has identified three structure framing geometries that are suitable and economical for this project: H-frames with I-string insulators, monopoles with I-string insulators, and monopoles with braced posts insulators. Both wood and steel material were considered for each structure configuration. For each configuration and material type, the evaluation considered suitability within the project constraints, cost, footprint, structural integrity, and maintenance considerations.

4.1 Structure Configurations

Burns & McDonnell reviewed several unique structure configurations and determined the following three structure types to be best suited as the standard single circuit structure type to be used in the Option E analysis. The results of the structure comparisons can be found in Table 4-1.

4.1.1 H-Frame with I-String

H-frame construction consists of two vertical poles with a horizontal member being used to attach the suspension insulators (See Figure 4-1). The suspension insulators support the phases in a horizontal configuration (all energized phases are at the same elevation). The United States Department of Agriculture Rural Utility Service (RUS) has designed families of standard structure geometries for 161-kV. A potential structure geometry is a TH-10, (page 75 of hyperlink to the left).

Structures utilizing suspension insulators are free to swing, which helps to reduce longitudinal loads which occur due to tension imbalances in the ahead or back span. Because the phases are arranged in a horizontal configuration, h-frame structures are typically shorter than monopole structures with vertical or delta phase configuration. However, h-frame structures typically require an additional shield wire as well as the construction of a second foundation.

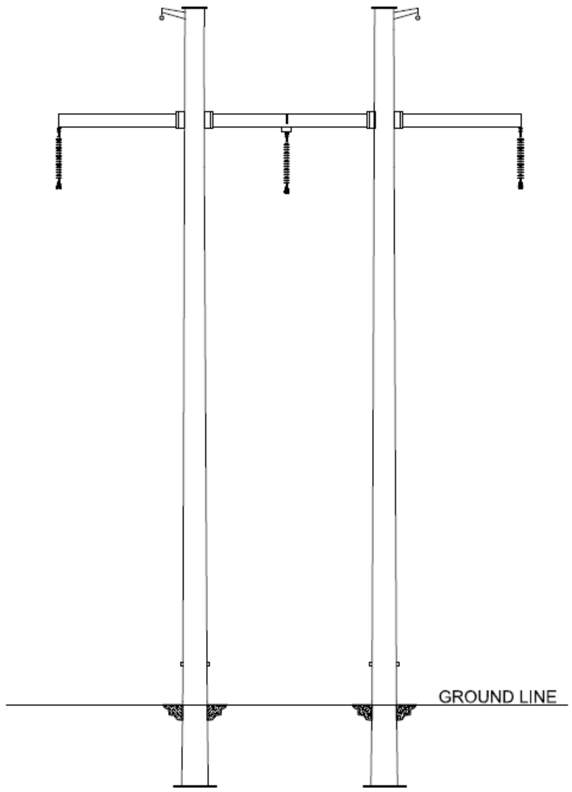

Figure 4-1: Conceptual I-string H-Frame Configuration

4.1.2 Monopole with I-String

Monopole construction consists of one vertical pole with three horizontal arms, supporting one phase per arm with I-string insulators and one shield wire positioned at the top of pole (see Figure 4-2). An RUS TU-1 (page 64 of hyperlink to left) is a representative example of a delta configuration, with each phase positioned at a unique elevation and on alternate sides of the pole. Monopole arrangements typically yield taller structures than an H-frame configuration but require a narrower ROW. Similar to the H-frame with I-string insulators, this monopole configuration will be able to reduce longitudinal loads from tension imbalances due to I-string insulator swing.

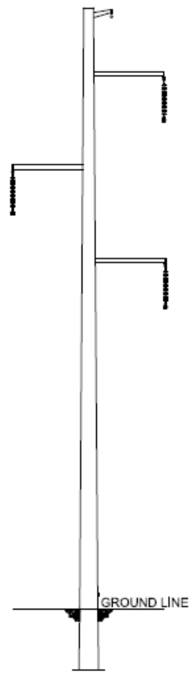

Figure 4-2: Conceptual I-String Monopole Configuration

4.1.3 Monopole with Braced Posts

Monopole construction with braced post insulators have a similar phase arrangement to the I-string insulator, but each phase wire is attached to a horizontal post insulator (See Figure 4-3). Conductors supported by braced post insulators do not blow out as far as I-string supported wires under wind conditions because the wire attachment location is fixed. This results in a narrower ROW width. Because the post insulators are rigid they translate longitudinal loads due to tension imbalances to the structure rather than swinging to relieve portions of the longitudinal load. Utilities that desire structures to be designed for longitudinal loadings caused by broken wires on unbalanced conditions typical do not use braced post insulators. Geometrically, the shield and phase wire arrangements are similar the TU-1 mentioned in Section 4.1.2 above.

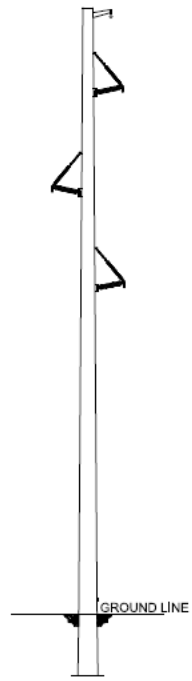

Figure 4-3: Conceptual Braced Post Monopole Configuration

Table 4-1: Tangent Structure Configuration Comparison

Structure Geometry	**H-Frame with I-String**	**Monopole with I-String**	**Monopole with Braced Post**
Structure Height	Phases are spaced horizontally; structures will be shorter than monopole options	Phases are spaced vertically; structures will be taller than H-frame option	Phases are spaced vertically; structures will be taller than H-frame option
Structure Width	Phases are spaced horizontally; structures will be wider than monopole options	Phases are spaced vertically; structures will be narrower than H-frame option	Phases are spaced vertically; structures will be narrower than H-frame option
ROW Width	Widest ROW width	Medium ROW width	Narrowest ROW width

Structure Geometry	H-Frame with I-String	Monopole with I-String	Monopole with Braced Post
Longitudinal Loads	Uses an I-string suspension insulator which can help reduce longitudinal loads due to insulator swing	Uses an I-string suspension insulator which can help reduce longitudinal loads due to insulator swing	Braced post insulators cannot reduce longitudinal loads or differential tensions. They are more prone to failure during extreme weather events (increased maintenance concern)
Structure Material	Wood or steel possible	Steel only	Steel only
Tangent Foundation	Direct embed	Direct embed	Direct embed

4.2 Structure Material Selection

For the structure types considered, wood and steel are two commonly used materials for structures designed at 161-kV voltage. The following sections describe some of the benefits and drawbacks of each material considered.

4.2.1 Wood

Wood poles have long been used by utilities as an aesthetic and cost-effective solution to transmission line design. Wood often can be an economic choice, depending on structure heights, span lengths, and wire loads. Wood has limitations at likely span lengths and proposed structure configurations of the project being analyzed. The American National Standard Institute (ANSI) specifies wood poles by “pole class”, which is related to the magnitude of horizontal load a pole can withstand without exceeding its allowable stress. The largest class wood pole available is an “H6” which is also only available in limited quantities with long lead times.

For the probable span lengths for this project (discussed further in Section 6.0) and assumed wire tensions, wood vertical monopole construction is impractical, as structure loading would exceed the allowable capacity of an H6 wood pole. The possibility of wood monopoles could be feasible if span lengths were reduced to approximately 400 feet instead of matching the average McCredie-Overton span lengths of 800 feet. This option would, however, double the quantity of structures required and possibly increase the required centerline offset distance from the existing 345-kV line.

Classed wood poles could be a feasible and economical structure material option used for the H-frame structure configuration. In this configuration two wood poles would support the assumed wire loads and span lengths so a pole class smaller than H6 is likely possible and could result in cost savings over a similar steel structure.

Due to the anticipated wire loads and structure heights, wood pole strength and available length would preclude wood from being used for any double or triple circuit construction discussed in Section 7.0.

4.2.2 Steel

Engineered steel poles are a viable option for all three proposed structure configurations. Steel poles allow for more flexibility in design and are not bound to the strength limitations of wood poles. Steel generally has a longer service life than wood and is not subject to rot, woodpecker damage, or other premature structure deterioration. Most steel pole manufacturers offer either a "classed" system of standard poles or a custom engineered solution based on the loading and configuration provided by the engineer. It is anticipated that all single circuit structures proposed could utilize a classed pole, however due to the quantity of structures and expected wire loading required for the project, a custom design may be more cost effective.

Table 4-2: Structure Material Comparison

STRUCTURE MATERIAL	WOOD	STEEL
Engineered product	No (variations accounted for by additional strength reduction factors used in design)	Yes (controlled material strengths)
Service life	Can be affected by decay, wildlife, and other natural contaminants	Typically more resistant to long term environmental effects (especially galvanized steel)
Strength	Strength limited to properties of natural materials. Lengths not possible for all configurations	Can be designed and constructed to near limitless strength requirements
Cost	Poles below class H3 are considered more economical than a comparable steel pole; poles above class H4 may not be more economical depending on wood availability	Cost is highly dependent on current steel pricing when poles are ordered

STRUCTURE MATERIAL	WOOD	STEEL
Material Lead Time	Poles below class H3 can be received relatively quickly compared to steel; supply of poles above class H4 can be limited and result in unavailability or long lead times.	Can take up to 40 weeks from time of original structure order
Design Flexibility	All hardware must be mounted using bolts and nuts; confined to framing allowed by manufactured hardware; hardware is readily available	Flexible hardware mounting possibilities; can create custom framing and mounting options to suit most applications
Design Suitability to Project	Suitable for single circuit H-frames only	Suitable for all monopole single circuit structures and any joint-use double or triple circuit structures

4.3 Existing 345-kV Structure Re-use

In addition to independent single circuit structure options CWL requested that Burns & McDonnell review the possibility of re-purposing the existing Ameren-owned 345-kV structures in a double circuit 345/161-kV configuration as another design solution. This would eliminate the need to install any new structures on shared ROW. As discussed below, is not feasible to attach the proposed 161-kV circuit to the existing Ameren 345-kV structures.

4.3.1 Existing Structure Strength

The existing 345-kV wood H-frame structures likely do not have adequate strength to accommodate the 161-kV circuit. Although structure loading drawings were not provided by Ameren for detailed loading analysis, transmission line structures do not often have capacity to withstand substantial load increases. The proposed 161-kV wire type is large, resulting in substantial wire loading, so it is unlikely the existing structure will suffice. Additionally, it is not practical to reinforce existing poles and foundations to withstand the additional circuit.

4.3.2 Electrical Clearances

The existing structures do not have sufficient height to maintain the required electrical clearance between the existing 345-kV and the proposed 161-kV circuits, in addition to the required electrical clearance from the proposed 161-kV circuit to the ground surface and/or other obstacles.

4.3.3 System Planning

In addition to the structural integrity and clearance concerns of the existing structure, having a combined double circuit 345/161-kV structure would need to be studied to determine the negative effects on the system reliability. When a lower voltage circuit (e.g. 161-kV) is located on a joint-use structure with a higher voltage circuit (e.g. 345-kV), the lower voltage can often act as a "sacrificial" circuit during a lightning event. Because the 161-kV circuit would utilize a shorter insulator string than the 345-kV circuit, lightning flashovers will generally be much more common on the 161-kV circuit, resulting in increased outages over a typical single circuit 161-kV transmission line.

5.0 PROPOSED CORRIDOR

In areas where the proposed Option E is adjacent to the existing McCredie-Overton 345-kV circuit, two horizontal distances must be calculated to determine the additional ROW width required and the proposed 161-kV centerline location; the required centerline offset between the existing 345-kV circuit and proposed 161-kV circuit and the distance from the proposed 161-kV circuit to the edge of the proposed ROW.

5.1 345-kV to 161-kV Spacing

The Ameren Report, discussed in Section 2.1, offered two conclusions regarding the centerline of the proposed 161-kV circuit:

1. *69 feet from the centerline of the 345kV transmission line to any part of the structure supporting a 161-kV transmission line.*
2. *71 feet from the centerline of the 345kV transmission line to any wire attachment point for a 161-kV transmission line.*

Based on a discussion with Ameren, these statements assume that the proposed 161-kV structures are to be located at midspan of the existing 345-kV structure locations, resulting in the most conservative (largest) offset assumption due to wire blowout considerations. During detailed design, these offset requirements could likely be reduced based on actual design information or by spotting the proposed 161-kV structure at locations immediately adjacent to the existing 345-kV structures.

5.2 161-kV to Edge of ROW

The required distance from the center of the proposed 161-kV line to the edge of ROW is dependent on structure configuration, conductor type, conductor tension, and conductor blowout. For the purpose of determining ROW width, two wind conditions were considered, a 48 MPH wind (6psf; NESC requirement) and 90 MPH wind (20.7 psf; NESC condition), to calculate the required ROW width. It is common industry practice to maintain the horizontal clearance associated with a building at the edge of the ROW with the conductor blown out under a 48 MPH wind. For the 90 MPH wind case, many utilities will require a small clearance often (0’ to 3’) between the blown-out wire position and edge of ROW. For this analysis, the 48 MPH wind condition controlled the minimum ROW width requirement.

As referenced in Section 5.0, each unique structure configuration will result in ROW width requirements, due to geometry and insulator differences. Table 5-1 summarizes the minimum additional ROW width (in addition to the re-use of the existing 150’ 345-kV ROW) required by structure type Figure 5-1 exhibits the same information.

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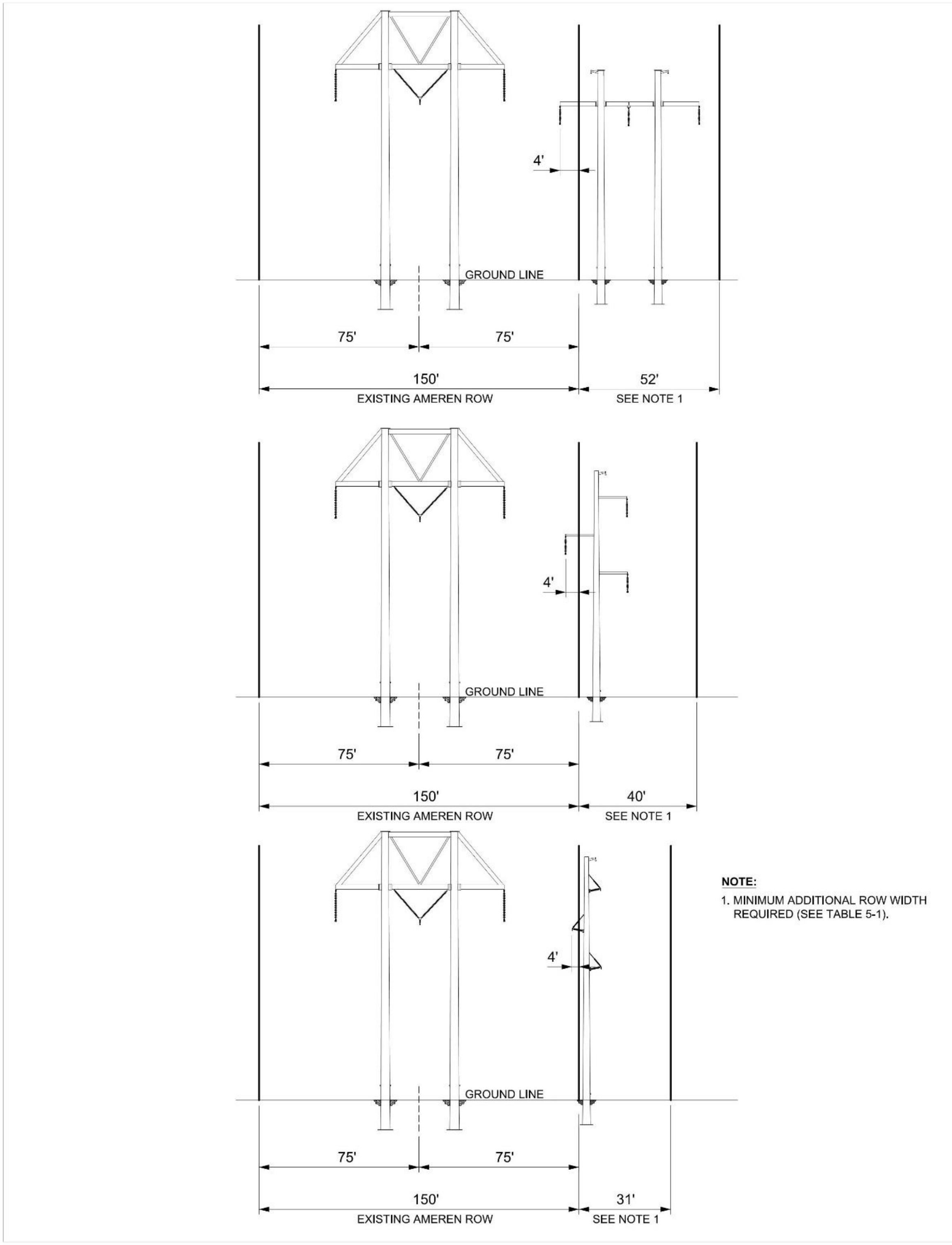
Table 5-1: Minimum Additional ROW Width Required

	H-Frame I-string	Delta Monopole I-string	Delta Monopole Braced Post
ROW width (ft)	52’	40’	31’

Figure 5-1: Minimum Additional ROW Width Required



6.0 STRUCTURE SPOTTING

In general, the intent of structure spotting is to attempt to minimize the total structure quantity and heights (cost considerations), while meeting the design requirements of the project (code and client requirements) and minimizing impact to adjacent landowners, the environment and project constraints (land use impacts). Structure spotting can be constrained by many factors such as: environmental, public involvement, archeological, among others. When attempting to route a line within an existing transmission corridor (as approximately 75% of Option E is), spotting adjacent to existing structures generally results in the narrowest required ROW. Additionally, structures positioned next to each other in a corridor is preferred aesthetically over structures spotted at mid span relative to the existing line.

Although detailed line spotting for the proposed 161-kV line was not performed as part of the scope of this analysis, Burns & McDonnell reviewed the spotting of the existing 345-kV circuit to examine the feasibility of spotting new structures adjacent to the existing 345-kV structures. Based on the existing line spotting, the average span of a future 161-kV line would be approximately 800’ in length, which is considered reasonable for a 161-kV circuit.

7.0 CORRIDOR CONSTRAINTS

Based on the Ameren Report and a high-level review of the proposed route by Burns & McDonnell, it was determined that Option E has several areas with corridor constraints due to existing infrastructure. Although there are feasible design solutions for each of the noted areas, there will be additional cost impacts for each of the solutions. The following sections summarize some of the key areas of interest and possible design solutions in these areas. Each section has been assigned a region number which corresponds to route map in Appendix A.

7.1 Bolstad Substation Area (Region 1)

From the intersection of Peabody Road and Brown Station Road eastward to Bolstad Substation, the proposed route is currently congested with existing overhead utilities. Based on a review of publicly available data, this corridor appears to contain three distribution circuits and two 69-kV circuits. To create room for the proposed 161-kV circuit, CWL staff suggested relocating the three distribution circuits underground to create room for the proposed circuit. Burns & McDonnell agrees with this approach.

7.2 Brown Station Road to Highway 63 (Region 2)

The Ameren Report mentions a double circuit distribution line on south side of the existing ROW between Ameren structures 623 and 643. It appears that the referenced line is a single circuit 69-kV line from Brown Station Road until approximately North Oakland Gravel, where a second 69-kV line joins. The existing structures are double circuit 69-kV until approximately Missouri Highway 63 where both 69-kV lines deviate from the Ameren ROW.

Starting at Brown Station Road and heading west until passing the Columbia COLT Terminal, the existing 69-kV circuit could be removed and placed on new double circuit 161/69-kV structures.

Alternatively, for this segment of the proposed route, the new 161-kV circuit could be placed on the north side of the ROW until North Oakland Gravel Road. The line would have to cross underneath the existing Ameren 345-kV line in at least two locations. These crossings would require Ameren cooperation, the replacement of approximately four existing Ameren-owned 345kV structures, additional 161-kV angle structures near the crossings, and the possible reliability concern of a wire dropped from the existing 345-kV circuit taking the proposed 161-kV circuit out of service. Offsetting the line to the north side of the ROW in this segment of line would be much costlier than rebuilding the existing 69-kV circuit on a joint-use structure.

Approximately 0.25 miles east of North Oakland Gravel Road, additional ROW width is not available due to a second 69-kV circuit in the corridor and the beginning of residential dwellings. From this point westward until Highway 63, the existing ROW contains the existing Ameren 345-kV line and an existing double circuit 69/69-kV line, one circuit owned by the City of Columbia and the other by Central Electric Power Cooperative (CEPC). Both the north and south sides of the ROW have residential dwellings along the current corridor and would not allow an expanded ROW to include the new 161-kV line. To utilize existing ROW, the two 69-kV circuits could be removed and replaced on new triple circuit 161/69/69-kV structures. This would require both the cooperation of CEPC and extensive outage planning, as well as more complex structure loading and unique designs.

7.2.1 Combined 345/161-kV Structure

An alterative to rebuilding the existing 69-kV circuits in this area, the existing 345-kV circuit could be rebuilt onto a new joint-use double circuit 345/161-kV structure. This option would require the Ameren 345-kV line to take an outage so that the existing structures in this two-mile area could be demolished and new double circuit structures built. It is unlikely that Ameren would desire to take such an outage. Additionally, the cost to construct this option would likely exceed the cost of rebuilding the 69-kV circuits in the corridor since the required structure and foundation sizes would be much larger and structures taller than the option presented in Section 7.2.

7.3 North Creasy Springs to North O Neal Road (Region 3)

Starting just east of North Creasy Springs Road to just west of North O Neal Road, there are line has several houses immediately adjacent to the edge of the existing 345-kV ROW. Using a vertical configuration 161-kV structure (narrowest possible option) on south side of the 345-kV line, the corridor is not wide enough to accommodate both circuits. Routing the line to the north side of the 345-kV line would result in similar situation with the added cost of having to raise approximately four 345-kV structures. Two possible options are offered below.

7.3.1 Double Circuit 345/161-kV

One option would include taking a temporary 345-kV outage while approximately one mile of Ameren’s existing line is removed and rebuilt with joint-use, double circuit 345/161-kV, vertical configuration structures. This would require Ameren’s cooperation, scheduling of an outage and system planning studies. One of the largest drawbacks of this option would be the increased cost associated with very large joint use structures. The electrical performance of the line will also need to be analyzed to ensure acceptable performance is obtained in the lower voltage 161-kV circuit. These joint use structures would

likely be very tall and visually intrusive in comparison with the existing 345-kV structures. The structures would need to be located on drilled shaft foundations.

7.3.2 Property Acquisition

Another option for this segment would involve purchasing the adjacent property and buildings and expand the ROW to construct and maintain a new circuit adjacent to the existing Ameren line. To determine the number of impacted buildings and parcels a detailed survey would need to be completed and detailed line design would need to be performed. Depending on the relative cost of the land acquisition and public relations concerns, this may another viable option in this segment.

7.4 Ameren Structure 679 (Region 4)

Approximately 0.5 miles south of the intersection of North Moreau Road and West Driskel Road, near Ameren structure 679 is a parcel that contains an existing metal building near the edge of the existing ROW. This building would be directly under the proposed 161-kV circuit. During detailed design, the 161-kV line could be analyzed to determine if the centerline can be moved closer to 345-kV line for this segment. If the proposed 161-kV line cannot be offset closer to the existing 345-kV circuit enough to provide clearance to the building, the existing building may need to be relocated or removed.

Another option to avoid this obstruction would include crossing to the opposite side of the existing 345-kV circuit. Based on discussions with the CWL, alternating the location of the proposed 161-kV route back and forth relative to the existing 345-kV route is undesirable and should be avoided if possible. It is doubtful that there would be any cost savings in crossing to the alternate side of the corridor compared to relocating or removing the building, as existing 345-kV structures would likely need to be rebuilt to accommodate the required crossing clearances.

7.5 Perche Creek Crossing Area (Region 5)

Option E crosses Perche Creek near the Breckenridge Park subdivision that is currently under construction. As a possible way to avoid visual or land impacts, Option E could be routed further west through this area. It should also be noted that based on publicly available data, on page 2 of Breckenridge Park Plat No. 1, a 110-foot future ROW for the extension of West Broadway is reserved. During final design it would be recommended to coordinate with appropriate departments to spot structures out of future roadway.

7.6 Perche Creek Substation Area (Region 6)

Option E turns east approximately 0.75 miles west of Perche Creek Substation, from this turn into the substation the corridor contains an existing CWL 161-kV wood pole H-frame line. Residential dwellings border the proposed route on both sides of the centerline with no room to expand the ROW. If the proposed entrance route to the substation is utilized, the existing 161-kV line would have to take an outage, be removed and rebuilt onto a double circuit, vertical phase configuration structure. Reuse of the existing wood poles would not be possible for similar reasons discussed in Section 4.3.

8.0 ACREAGE IMPACT

Using the parcel data provided by CWL, an acreage impact analysis was performed. This analysis was based on the assumptions from Section 5.0 and Table 5-1. Option E affected 94 parcels, the details are shown in Table 8-1. Table 8-2 was provided entirely by and for the benefit of CWL.

Table 8-1: Acreage Impact of Additional ROW required

Land Use Category	Acreage
Agricultural	5.7
Church	0.1
Commercial	0.4
Driveway	0.1
Forested	25.7
Industrial	1.7
Pasture/Grassland	38.3
Pond	0.4
Recreational	1.4
Residential	8.9
Stream	0.2
Substation	0.3
Total	83.2

Table 8-2: Acreage Impact by Zone

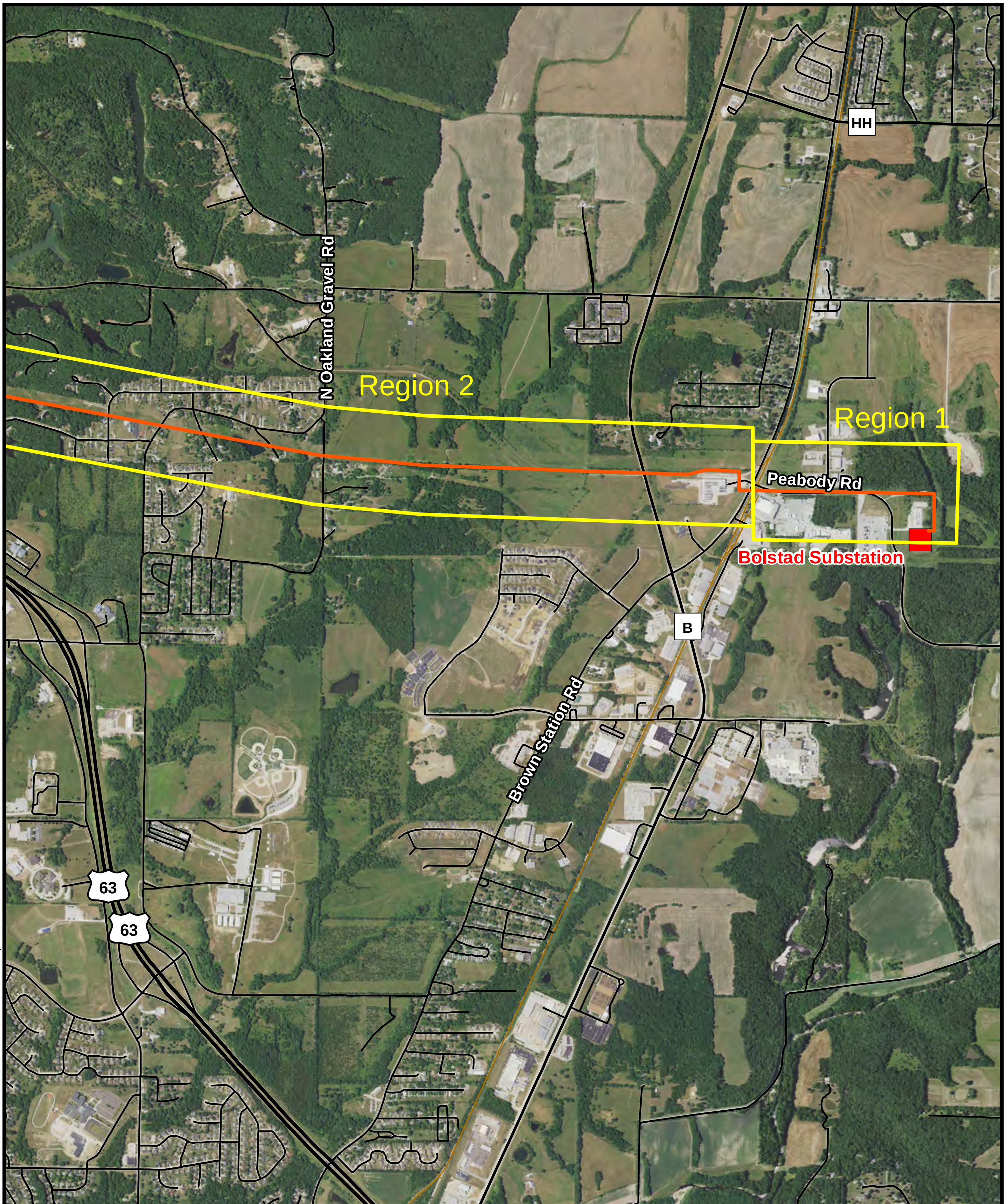
District	Zone	Acreage
IG	City	1.66889
M-BP	City	0.332443
PD	City	0.699123
R-1	City	10.469
	County	3.297172
A-1	County	6.206549
A-2	County	27.37848
A-R	County	19.77103
R-M	County	4.450339
R-S	County	8.591924
REC	County	3.687325

9.0 SUMMARY

Burns & McDonnell has analyzed the feasibility of the proposed Option E, which parallels the existing Ameren-owned McCredie-Overton 345-kV transmission line for the majority of the route, as directed by the CWL. Based on the project information received and analyzed, Burns & McDonnell believes that the proposed route is feasible, although there are a number of route obstructions which will need to be addressed and will ultimately have additional costs that would not be recognized from an unobstructed route. The westerly portion of the route, parallel to the existing 345-kV circuit, provides an economical unobstructed route. However, the eastern half of the proposed route has several obstructions that may benefit from diverging from the existing corridor and re-routing the line elsewhere to minimize cost impacts

For the proposed route, Burns & McDonnell would recommend a typical steel I-string monopole with delta phase configuration in areas not constrained by ROW, existing utilities, or other obstructions. Because ROW constraints are common throughout the proposed corridor, the additional easement width required from the use of an h-frame type structure may not be practical for this application. Wood is often recognized as an economical structure material for transmission lines, but for the assumptions used as part of this project, standard wood monopoles do not have the required strength capacity to support the wire types, design loads, and span lengths required for this application. Additionally, Burns & McDonnell recommends the use of I-string insulators as opposed to braced post insulators, to allow for the relief of longitudinal loads and the expectation of reduced maintenance and repair during extreme weather events.

Appendix A **-OPTION E MAP**



NORTH

0 1,000 2,000

Feet

LEGEND

Existing Substation

Proposed Route

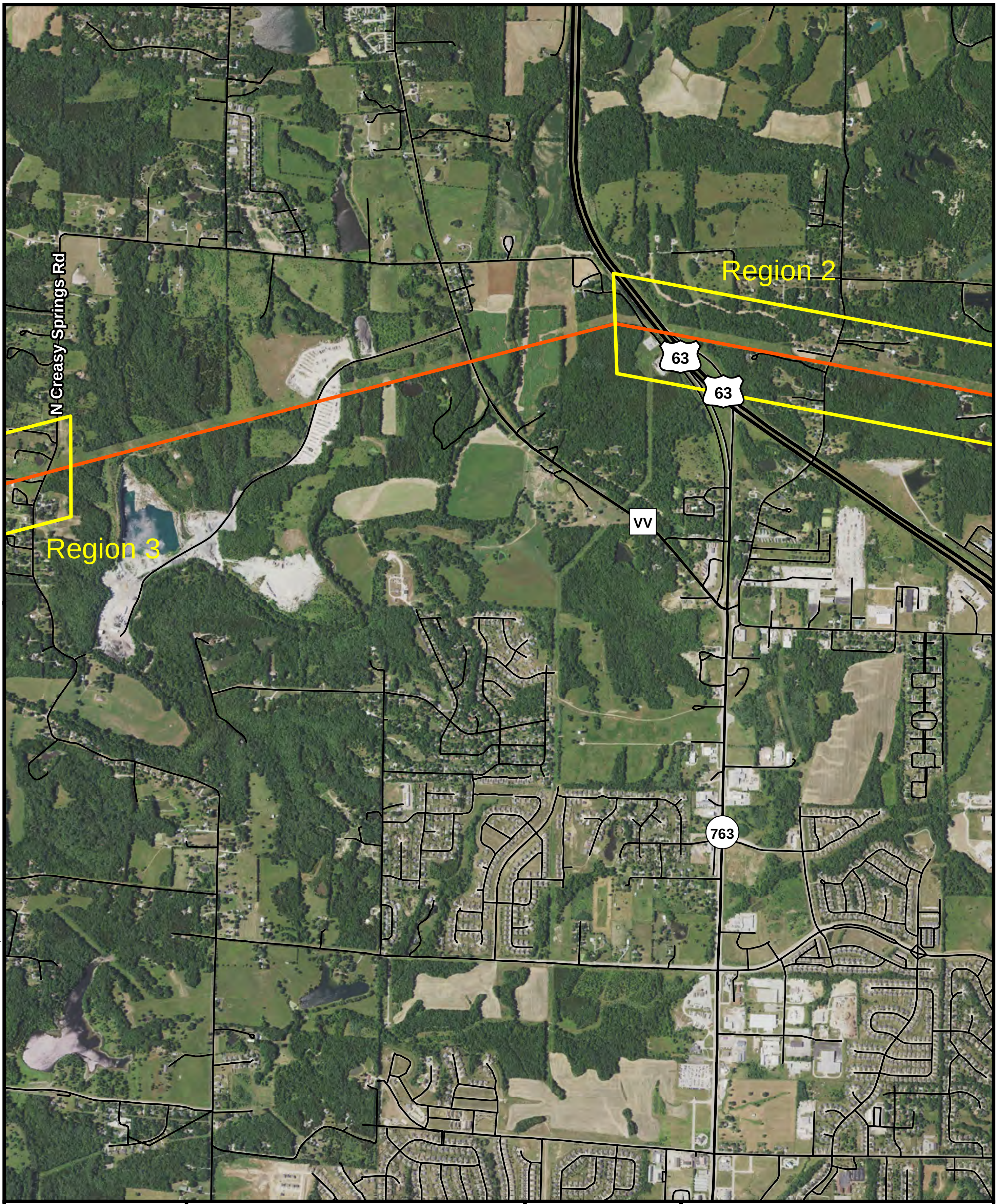
See Section 7 of report for information regarding region numbers.

BURNS McDONNELL

Columbia Water & Light
Option E
Sheet 1 of 4

Source: USDA NAIP 2016 Aerial Photography; TIGER Roads; Burns & McDonnell.

May 03, 2018



NORTH

0 1,000 2,000

Feet

LEGEND

Existing Substation

Proposed Route

See Section 7 of report for information regarding region numbers.

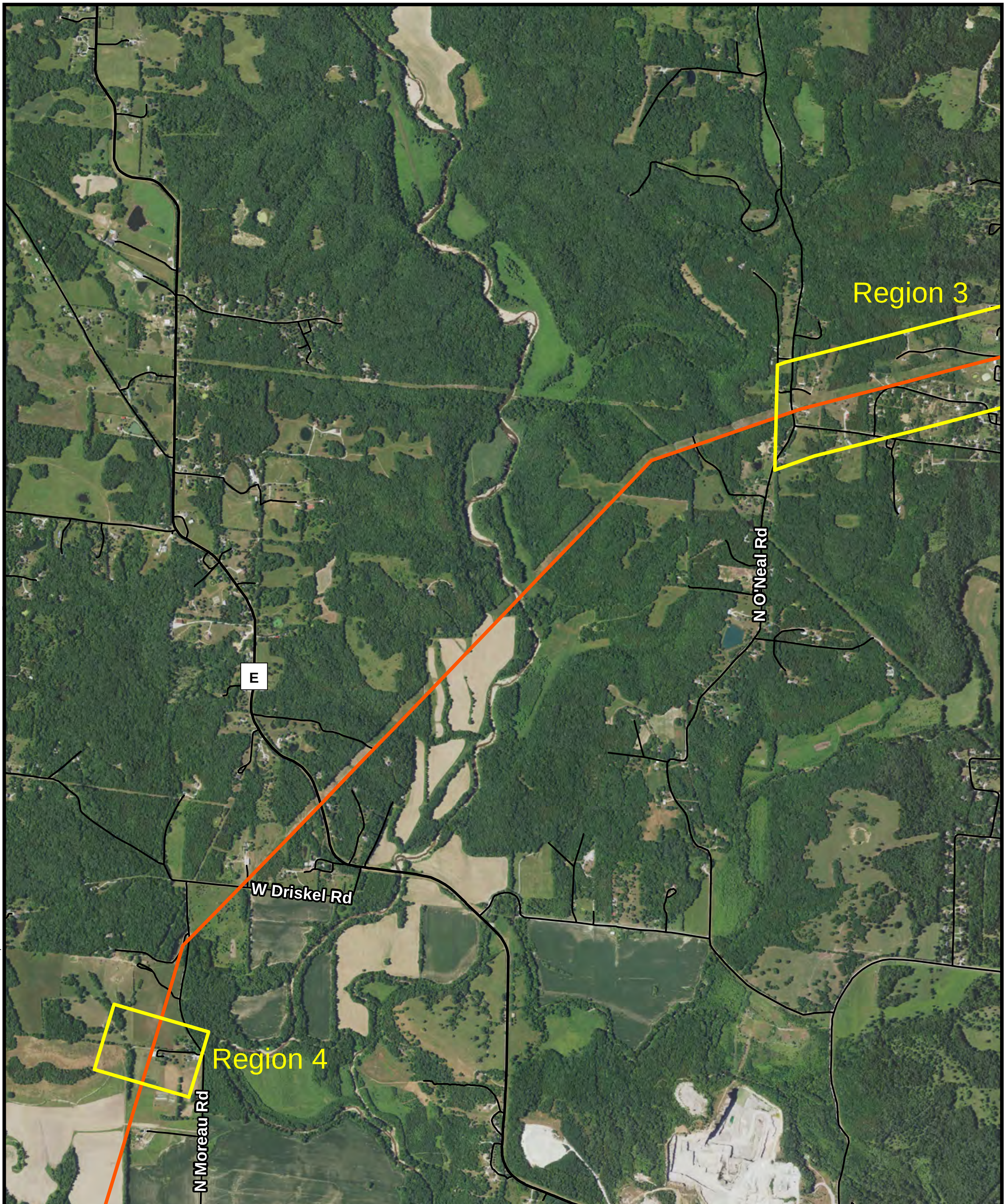
BURNS McDONNELL

Columbia Water & Light
Option E
Sheet 2 of 4

Path: \\bmcd\dfs\Clients\TND\ColumbiaMO\104146_RouteEeval\Studies\Geospatial\DataFiles\ArcDocs\Columbia_Water_and_Light_Option_E_Regions.mxd rfraser 5/3/2018

Source: USDA NAIP 2016 Aerial Photography; TIGER Roads; Burns & McDonnell.

May 03, 2018



NORTH

0 1,000 2,000

Feet

LEGEND

Existing Substation

Proposed Route

See Section 7 of report for information regarding region numbers.

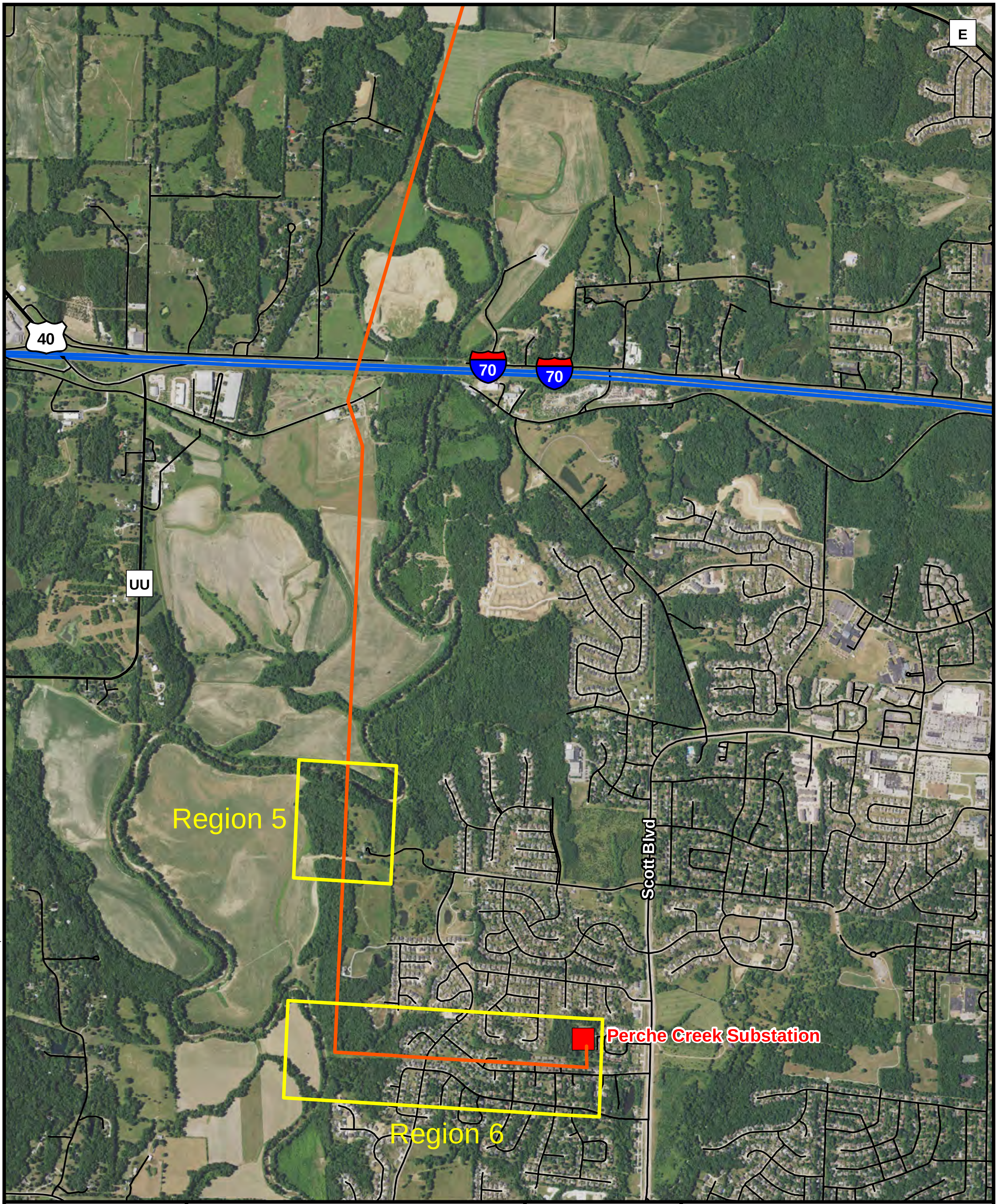
BURNS McDONNELL

Columbia Water & Light
Option E
Sheet 3 of 4

Path: \\bmcd\dfs\Clients\TND\ColumbiaMO\104146_RouteEeval\Studies\Geospatial\DataFiles\ArcDocs\Columbia_Water_and_Light_Option_E_Regions.mxd rfraser 5/3/2018

Source: USDA NAIP 2016 Aerial Photography; TIGER Roads; Burns & McDonnell.

May 03, 2018



NORTH

0 1,000 2,000

Feet

LEGEND

Existing Substation

Proposed Route

See Section 7 of report for information regarding region numbers.

BURNS McDONNELL

Columbia Water & Light
Option E
Sheet 4 of 4

Path: \\bmcdfs\Clients\TND\ColumbiaMO\104146_RouteEeval\Studies\Geospatial\DataFiles\ArcDocs\Columbia_Water_and_Light_Option_E_Regions.mxd rfraser 5/3/2018

Source: USDA NAIP 2016 Aerial Photography; TIGER Roads; Burns & McDonnell.

May 03, 2018

BURNS & McDONNELL

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